§11. Development of Electron Bernstein Emission Diagnostics for Electron Temperature Measurement in High Beta Plasmas

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Electron Bernstein Emission (EBE) radiometry was proposed to measure time evolutions of the electron temperature profile in the over-dense high-beta plasma. Electron Cyclotron Emission (ECE) radiometry is widely used to measure electron temperature time evolutions, but the ECE cannot propagate outside the plasma due to the cut-off in the over-dense plasma, while the electrostatic EBE wave cannot propagate in the vacuum. The EBE wave should be converted to the electromagnetic ECE wave to be measured. The mode conversion processes were requested in the EBE radiometry. In the B-X-O mode conversion, the Bernstein mode first converted to the eXtraordinary (X) mode at the upper hybrid resonance, and then the X-mode converted to the Ordinary (O) mode at the O-mode cutoff. The EBE wave can be detected as the converted O-mode wave with the parallel refractive index $N_{//}$ to the magnetic field. The oblique viewing should be prepared for the EBE radiometry with the B-X-O mode conversion.

In the EBE radiometry with the B-X-O mode conversion, the advanced antenna system with good directionality has been required for the oblique viewing. A square-waveguide Phased-Array Antenna (PAA) system has been developed in Kyushu University. The antenna performance was tested at the low power test facilities. The coherent wave was fed into the antenna elements in the phased array. The field distribution radiated from the PAA was well explained with the Kirchhoff Integral evaluation. The operating frequency range was 8-14.5 GHz.

In the EBE diagnostics, incoherent thermal emission should be measured with good directionality with the PAA. The PAA performance was based on phase adjustments among the antenna elements. The PAA performance to receive the incoherent emission was checked at the low power facilities. A broadband noise source was prepared as an incoherent thermal emission source. The selectivity of the measuring frequency became important in the incoherent emission measurements. The super heterodyne detection system was developed to measure the specific frequency component in the broadband thermal emission. The system was composed of image-rejection mixers and IQ demodulators and narrow-band filters. Figure 1 shows time evolutions of IQ demodulated signals at the super heterodyne detection. The selected measuring frequency was 8.07 GHz, and it was measured as a 455 kHz frequency component at the super heterodyne detection. The two port signals were measured at the different PAA elements (at [P5] and [P8] shown in the figure) to obtain its phase difference. The launching and receiving antennae were a horn antenna and a prototype PAA, respectively. Figure 2 shows a Lissajous figure drawn by the 455 kHz IQ (cos- and sin- function) signals. The launching position was scanned to measure the phase difference evolution depending on the propagation distance. The phase difference was detected by correlation analysis within 8 μs between the launching and receiving ports. Figure 3 shows phase differences measured between the two ports as a function of the propagation difference. The proper dependence of the phase difference evolution on the propagation distance was obtained with the correlation analysis. The PAA performance will be obtained by the correlation technique.

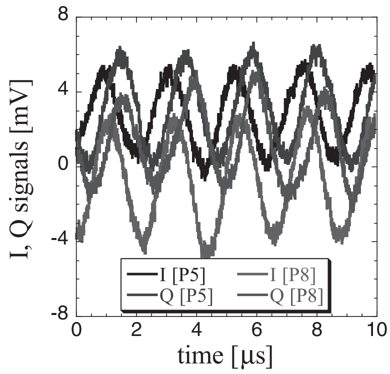

Fig.1: Time evolutions of IQ demodulated signals at the super heterodyne detection system for the EBE diagnostics.

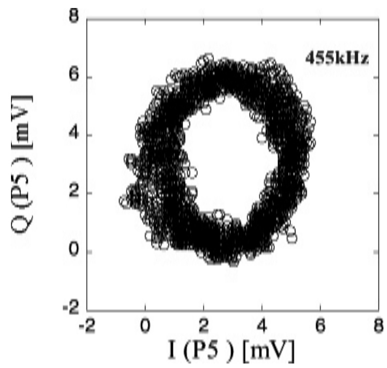

Fig.2: Lissajous figure drawn by the 455 kHz IQ (cos- and sin- function) signals.

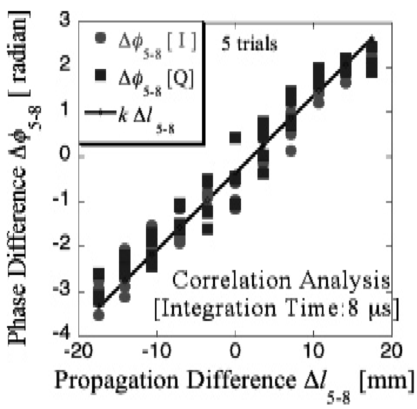

Fig. 3: Phase differences measured between the two ports as a function of the propagation difference.